Proceedings of the National Academy of Sciences
Vol. 67, No. 2, pp. 887–897, October 1970

A Lesson from the Smog Capital of the World

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Contributed to Symposium on Aids and Threats to Society from Technology, April 29, 1970

Abstract. The history of air pollution control in the Los Angeles area shows a gradual transfer of authority from city and county to state and federal government. The relative role of the various levels of government is discussed. Regional control will become increasingly important with standards set or approved by state and federal authorities. Progress is noted in the control of both stationary and moving sources, but long-range planning of the development of our urban complex with an overriding regard for its effect on the environment is needed if the technological innovations are to keep pace with the demands of an ever-increasing population.

Nowhere within recent times has there been a more publicized effort to control air pollution and, perhaps, nowhere has there been more controversy than in the City of the Angels. In other areas, prolonged air pollution episodes were usually related to the combustion of coal; visible plumes from industrial stacks and chimneys readily suggested a solution. The trouble in Los Angeles was different. Almost no coal was burned in the area and the origin of the eye-irritating haze, accompanied by a peculiar "bleaching-solution" odor, was a disturbing mystery. Soon there came additional evidence that there was something seriously wrong with the air over Los Angeles: rubber manufacturers received complaints about rapid deterioration of their products; plant scientists, Drs. J. Middleton and F. Went, detected widespread damage to soft leaf vegetation not observed anywhere else before.

In 1942, in the midst of the World War II, the first attack of eye irritation occurred. This was assumed to be coming from a synthetic rubber plant near the center of the city. The attacks disappeared near the end of the war when the plant was closed. However, there were renewed attacks of pollution and many suspects were, of course, named: refineries, chemical factories, open burning, and automobiles, headed the list, but not one of these operations could explain the almost daily occurrence of the new pollution called "smog." Smog, a contraction of smoke and fog, remained a household word even though the chemists later established a totally different origin. To many, Southern California had been a haven to escape from the crowded and unsavory conditions in some of the eastern cities, and when they were confronted with the highly objectionable smog clouds, the reaction was immediate. The public and the press demanded action.

Fortunately, the legal tools were available to the State to attack this problem in a manner consistent with our constitutional form of government. The Constitution of the United States reserves the right of the States to use police power to protect the health, safety, and general welfare of the inhabitants. Under the Tenth and Fourteenth Amendments to the Constitution, the States themselves—or the States acting through an adequate political agency—have power to enact reasonable laws to regulate emissions of smoke or other forms of air pollution. An excellent account of the development of air pollution legislation in Los Angeles and in the State of California has been written by Harold W. Kennedy, former County Counsel for the County of Los Angeles.[1]

Early in 1945, the Board of Supervisors of Los Angeles County created the office of Director of Air Pollution Control, with the power to enforce air pollution ordinances. Later in the year, the Supervisors adopted an ordinance to prohibit excessive smoke emissions from any source, and other ordinances to strengthen the county program of air-pollution control.

By 1946, it was plain that air pollution disregarded political boundaries. At the urging of the Los Angeles County Supervisors, many of the cities in the County adopted ordinances identical to those adopted by the County. However, this still left something to be desired. On the one hand, the air pollution problem clearly superseded city boundaries, but the County had no enforcement powers within city jurisdictions. Moreover, the tradition of home-rule government was firmly established in California. On the other hand, there was the need for a single agency to assume both the responsibility and the legal authority for enforcement of air pollution control.

The State Air Pollution Control Act of 1946 (Stewart Bill) satisfied these conflicting demands by adopting a proposal by the Los Angeles County Counsel's office and assigning jurisdiction for control of air pollution to the County. This bill created in each county of the State an air pollution control district, which could be given power to act upon resolutions by the County Board of Supervisors. Immediately after this law was enacted, the Los Angeles County Air Pollution Control District (LACAPCD) was thus empowered, and districts were later formed in Orange County (1950), San Diego and Riverside (1955), and San Bernardino County (1956).

THE FIRST DECADE OF CONTROL

The Los Angeles County Air Pollution Control District

Dr. Louis McCabe was the first Air Pollution Control Officer of the LACAPCD. He initiated stringent restrictions on emissions of sulfur dioxide and smoke from power plants, the petroleum industry, and the chemical and metallurgical industries. After about two years of actively reducing these emissions, Dr. McCabe left the APCD, expressing his confidence in the effectiveness of these measures; he predicted that the smog problem would be solved in two years.

Wisely, Dr. McCabe had foreseen the need to know more about the nature of the problem in Los Angeles and had organized a research program running

parallel with the control activities. This program showed clearly that Los Angeles pollution was quite different from the smoke problems common to many industrial eastern cities. It was during that period that I made public my findings on the nature of the eye-irritating, plant-damaging smog. I attributed it to the photochemical oxidation of organic materials originating with the petroleum industry and automobiles.[2]

Synthetic smog prepared by combining hydrocarbons with ozone or exposing a mixture of oxides of nitrogen and gasoline vapor to sunlight was shown to cause the typical markings on plant leaves seen after smog attacks.[3] Laboratory experiments disclosed the formation of ozone in these photochemical reactions and gave the explanation for the unusually high oxidant values measured on smog days.[4,5]

The Control District testing crews investigated hydrocarbon losses from petroleum processing and found these emissions to be quite large. One of the smaller refineries, for example, was losing about 40 tons (about 12,000 gallons) per day of gasoline from a separator pond in which water was separated from gasoline emulsions. The refinery verified this and other sources of emissions and published the results of these investigations. This straightforward action had a profound effect in causing a general clean-up in the petroleum industry.[6]

Mr. Gordon P. Larson replaced Dr. McCabe as the Air Pollution Control Officer of Los Angeles County, and continued, with great vigor, the reduction of emissions at refineries and other industries. He also undertook the control of emissions from open dump burning and backyard incinerators and made the initial contacts with the automobile industry. However, in this energetic drive to control what were considered the main sources of air pollution, Mr. Larson acquired the opposition of the petroleum, chemical, and other industries, and, worst of all, the individual citizen with his backyard incinerator. This accumulation of pressures was politically unacceptable, and the Supervisors, who had praised Mr. Larson at the time the public called for quick air pollution control action, were not now ready to defend him.

His successor, Mr. S. Smith Griswold, saw the need for prompt and forceful action and gave his deputy, Mr. Louis Fuller, a former police captain, a free hand in organizing a strong enforcement and inspection team. The uniformed enforcement officers with sheriff's credentials, in their clearly marked cars equipped with two-way radios, did much to establish confidence in the control efforts of the District.

The new control officer also recognized the great importance of a strong public-relations and information department, which could prepare and inform the citizens that restrictions on their activities were unavoidable and in their best interests—a task which had been neglected in the past.

In the meantime, the Stanford Research Institute was employed by the Western Oil and Gas Association to study the air pollution problem in Los Angeles. They published a series of reports confirming the formation of oxidant in the atmosphere, but denying the photochemical mechanism of oxidant formation involving hydrocarbons and oxides nitrogen. This controversy over the nature and causes of the eye-irritating smog and its plant-damaging properties, as well

as the importance of the emissions from the petroleum industry and from automobiles, became disturbing to the Los Angeles area community leaders. A new organization was formed, the Southern California Air Pollution Foundation, under the leadership of Dr. L. B. Hitchcock. The Foundation, largely supported by several industries, sponsored research in various aspects of air pollution problems and published 33 reports. Other organizations interested in the smog problem were the Southwest Research Institute and the American Petroleum Institute. The latter sponsored a research project together with the Franklin Institute, under the direction of Dr. W. Scott. The project confirmed the photochemical nature of the smog.[7] At about the same time, confirmation came from Drs. R. D. Cadle[8] and F. E. Littman[9] at the Stanford Research Insititute, both working under a contract from the Air Pollution Foundation. These confirmations were disclosed at a historic meeting of the American Chemical Society in September 1955 and at a conference on Chemical Reactions in the Urban Atmosphere in February 1956, organized by the Air Pollution Foundation. This signified the end of the controversy. The photochemical origin of Los Angeles smog through the action of sunlight on a mixture of oxides of nitrogen and hydrocarbons was no longer in dispute.

Fortunately, the control authorities did not wait for this general agreement and had prepared a detailed emission balance for the County which showed beyond any doubt the large contributions of both the petroleum industry and automobiles to the release of hydrocarbons, and of automobiles and fuel-burning power plants to the emission of oxides of nitrogen.[10]

The control of escaping hydrocarbons had progressed quite satisfactorily; vapor recovery by the petroleum industry became part of normal good housekeeping. This industry estimated that the losses in gasoline before control was about 120,000 gallons a day. The County chemists' estimate was double this amount. At present, this loss has been reduced (through extensive control, especially, good housekeeping) to about 30,000 gallons, or less than half a percent of the gasoline sold in this area. With the petroleum industry actively engaged in controlling their emissions, the control agency directed its attention towards the automobile industry.

Motor Vehicle Control

The search for the origin of hydrocarbons in the air over Los Angeles led to the discovery that the combustion in the automobile engine was not as complete as the industry had assumed and that considerable quantities of carbon monoxide and unburned hydrocarbons were actually released. Early estimates by the County and the Stanford Research Institute made in 1951 and 1952 had indicated that tail-pipe losses of hydrocarbons amounted to 850 tons per day and those of carbon monoxide to 5000 tons per day. This incomplete combustion resulted in a 10–15% loss in the combustion value of the fuel and, in addition, furnished a basic ingredient for the smog reaction. Motor vehicles are also the main contributors to the initiator of the smog reactions, the oxides of nitrogen that are formed from nitrogen and oxygen of the air at the high temperature prevailing during the explosion.

After these findings became public, individual auto companies and the Coordinating Research Council of the automobile industry initiated research to reduce motor vehicle emissions, a subject which apparently had been completely overlooked. At first, the emphasis was on reducing emissions during engine deceleration, which was thought to be most important, but this was found to be only a part of the total vehicular emissions. The research efforts were expanded to develop catalytic and afterburner devices to be used on the exhaust gases. Both of these types of devices were found to be effective, but the catalytic systems were rendered ineffective in a relatively short time by the lead in the exhaust. Many people, research groups as well as independent inventors, were developing systems for reducing automotive emissions. However, all of these research efforts were terminated when the auto industry itself started to control emissions through engine modifications.

In the meantime, there had developed a much better understanding of how the automobile contributes to the production of hydrocarbons and oxides of nitrogen. A significant finding was that the loss of hydrocarbons was not confined to the exhaust but that substantial quantities of hydrocarbons are released through the crankcase vent and evaporation from the carburetor bowl and gasoline tank. It is at present generally accepted that these losses from the average uncontrolled car are: 65% from the exhaust, 20% from the crankcase, and 15% from evaporation.

THE SECOND DECADE

Control After 1960

Although the state law had assigned the major role in control of air pollution to the counties, practical experience taught that state government could not escape a major responsibility in some general aspects of this control. The formation of the Bureau of Air Sanitation in the State Department of Public Health foreshadowed the more prominent role which the State was going to play. This Bureau, under the direction of Mr. John Maga, was charged with the study of the causes of air pollution, with giving aid to county districts in abating air pollution, and with determining effects on health and other effects of air pollution. In 1959 the Bureau set the first quality standards for ambient air in California—a most significant conclusion of the first ten years of pioneering work.

In 1960, the State of California took over the responsibility of control of motor vehicles by creating a Motor Vehicle Pollution Control Board.[11] This was a logical move since moving sources, such as automobiles, do not respect local boundaries. This transfer of authority had the added advantage that the whole State could now exercise pressure on the automobile industry. The new Board was given the duties of curtailing the emissions from motor vehicles in an orderly way by setting emission standards and adopting testing procedures followed by certification of control devices.

The Board's efforts resulted in the installation of crankcase devices on all California cars since the 1961 models, and exhaust devices were installed on

California cars beginning with the 1966 models. Controls to prevent loss of gasoline by evaporation are standard equipment on the 1970 models.

The Mulford-Carrell Act of 1967 dissolved the Motor Vehicle Pollution Control Board in California and created the Air Resources Board with broad powers and authority, and with the ultimate responsibility for the air pollution programs in California. The California Air Resources Board divided the State into eleven air basins, each one having a common air mass and common air pollution problems. For each of these basins, ambient-air quality standards were adopted. The enforcement of these standards is still primarily a function of local government, but emission programs have to be submitted to and approved by the State Board.

In the meantime, the federal government had not been idle and its activities betray a similar shift to a more centralized occupation with environmental matters. The Federal Clean Air of 1963, its amendments in 1965, and the Air Quality Act of 1967 put the federal government prominently into the picture. These laws made federal funds and technical assistance available to state and local air pollution control agencies. The federal government also preempted the field in motor-vehicle emission control and ordered the states to adopt air quality standards and plans for their implementation. The federal government designated two of the California air basins, the Bay Area and the South Coast Region, as federal air-quality control regions.

California alone, among all the states, was able to receive waivers of federal preemption of motor vehicle control. California was able to prove that it had a pressing need for vehicle emission standards more stringent than those adopted by the federal government for the remainder of the country. However, it now appears that for the 1975 model year, the federal standards will be at least as strict as those adopted by California. If this is so, California will not be able to obtain waivers of federal preemption.

South Coast Air Basin

The control of air pollution has gone through an evolutionary process. Slowly, but inevitably, government has recognized that conservation of the quality of air in one community cannot be separated from that of a neighboring one. The problems of Los Angeles city and those of the county have been submerged in the larger problem of the *South Coast Air Basin.* This Basin philosophy was officially recognized by the action of the State Air Resources Board and the federal government by adopting ambient air standards for the whole region. Future decisions on air pollution control will be increasingly based on their impact on the region rather than on a city or county.

Publications of the Air Resources Board give detailed information on: the extent of the South Coast Air Basin[12a]; the state ambient air standards[12b]; the emission standards for various model years of motor vehicles[12c]; the air pollutant emissions[12d]; emissions prevented[12e]; and air pollution levels.[12b]

Meteorological and geological features determine the extent of this region. A series of mountain ranges, whose upper elevations reach over 10,000 feet above

sea level, form a semicircular barrier surrounding the South Coast Air Basin. A gentle sea breeze moves pollutants inland during the daytime, and an even weaker land wind reverses the smog cloud during the evening and night. Temperature inversion conditions during most of the year aggravate the normal condition of poor ventilation in the region.

The area in the natural Basin includes a small coastal strip in Santa Barbara County, all of Ventura and Orange Counties, the major portion of Los Angeles County, and small portions of western San Bernardino and Riverside Counties. Since the mountains restrict the level of human activity and the effects of the resulting pollution to the Basin area, the boundaries of the Basin were generally drawn along the major ridge lines of the mountains.

Of the approximately 37,000 square miles in the six counties, only about 9,200 square miles are included in the South Coast Air Basin. However, the Basin contains over 95% of the 10 million people in these counties—about half the population of California. It is one of the fastest-growing areas of the country and has increased its population by 25% in the last 8 years. The number of automobiles owned in the Basin is 5,300,000. The power-generation capacity is 10,300 MW, with a potential daily emission of 200–350 tons of oxides of nitrogen and 140–1200 tons of sulfur dioxide per day, depending on the fuel used. The plants in Los Angeles County are now entirely converted to the use of gaseous fuel; other counties in the Basin have converted from high-sulfur to low-sulfur oil. Throughout the Basin, conversions to the use of gaseous fuel or to low-sulfur oil await the availability of the fuels.

The extensive list of the types, magnitude, and sources of emissions in the South Coast Air Basin prepared by the Air Resources Board has been most useful in guiding the control effort.[12d] The following abbreviated table of emissions (Table 1) from mobile and stationary sources shows clearly that the auto-

TABLE 1. *Average emission of air contaminants into the atmosphere in the South Coast Air Basin, 1968 (tons per day).*

	Stationary sources	Mobile sources	Total emissions
Hydrocarbons	900	2,600	3,500
Carbon monoxide	100	13,900	14,000
Oxides of nitrogen	440	1,000	1,440
Particulate matter	110	130	240
Sulfur dioxide	320	60	380

mobile is the major source of hydrocarbons, oxides of nitrogen, and carbon monoxide. However, one-third of the emission of the oxides of nitrogen originates, from the burning of fuel in stationary sources, and these sources cannot, therefore, be neglected.

The use of such compilations, however, requires good judgment, and involves more than comparing gross tonnages of pollutants regardless of their relative health or nuisance effects, as has often been done in recent years. The emissions from mobile sources represent over 90% of the total, with stationary sources contributing less than 10%. However, if we consider the photochemical part

of the smog, to which the carbon monoxide does not contribute, we arrive at the more credible figure of 30% as the contribution of stationary sources.

California Standards for Ambient Air Quality and for Emissions

As a basis for all efforts at air pollution control, the California Air Resources Board has adopted ambient-air quality standards based on health and aesthetic considerations.

These standards establish a goal which the control authorities try to meet by establishing legal maximum levels of emissions for polluting activities of the community. The County Districts have set such emission standards for stationary sources; those for motor vehicles have been adopted by the California Air Resources Board applying throughout the State.

The 1975 goals set for the control of car emissions are: 85% reduction in the emission of carbon monoxide, 95% for hydrocarbons, and 75% for the oxides of nitrogen. Proposed federal standards force an even greater emission control of nitrogen oxides, namely 88%.

The ability to meet the ambient air levels is determined by the available control techniques but also to a high degree by the ability of the region to accommodate pollution. This capacity varies with the height of the inversion. For example, for a 1,000-foot inversion height, taking into account the sloping terrain, the total volume of the region below the inversion layer is about 300–600 cubic miles. Once we know this "region constant," it is possible to calculate the critical emission load for any other contaminants and, in addition, how much the emissions have to be reduced to meet the clear air standard. For example, the present emission of 1440 tons of oxides of nitrogen released per day requires at least an 80% reduction to meet the ambient air standards. The control of the oxides of nitrogen is now underway at power plants, and a beginning has been made with the reduction of this pollutant in automobile exhaust. The present control program is, however, far from satisfactory, since only a meager reduction of 30% will be reached by 1985, and soon thereafter, if no other measures are taken, the oxides of nitrogen will increase again.

All our available technology has to be mobilized to meet this challenge. Research organizations in government, universities, and industries all need to play a part in finding ways to improve the technology of our pollution control. As long as we do not have such improved control technology, our only choice is to refuse the operation of new polluting industries in areas of limited ventilation capacity.

ENVIRONMENTAL MANAGEMENT PROBLEMS AND NEEDS

Our experience in the South Coast Air Basin has made us aware of problems other than technological ones. These problems will have to be solved if there is to be effective air pollution control.

In the South Coast Air Basin, county, state, and federal agencies are all involved in air pollution control. There are county APCD's operating in the Basin in Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties,

and Santa Barbara County is controlled by its Health Department. Each of the county organizations has its own regulations concerning air pollution. The federal government has a natural role in interstate air pollution problems. The federal and state governments should have a close cooperation, especially regarding the mobile sources of emissions. But the number of agencies concerned leads to considerable fragmentation in decision-making.

Federal law makes the State of California ultimately responsible for the program of air pollution control in the South Coast Air Basin, which has been designated by the federal government as the Metropolitan Los Angeles Air Quality Control Region. There is a definite need for a single agency to take responsibility for the program in the Basin.

A sensible solution to the problem would be to have the control districts continue in business and to have a Regional Coordinating Council which would be responsible to the State. Such a council could be made up of representatives from the county agencies. As an alternative plan, there might be a Regional Directorship as a part of state government, which would take responsibility for the Basin program and coordinate the local programs. This would, in addition, greatly ease the problem of the siting of power plants in the Basin. As pointed out earlier, no more fossil-fuel power plants should be built in the Basin unless the emissions from such plants can be virtually 100% controlled, which is not very likely. On the other hand, the population in the South Coast Air Basin is expected to double in about 20 years, and the power demand will more than quadruple in that time period.

There is no group which is qualified to give a decision on the siting of power plants with any consideration for the effects of the plants on the environment 10 to 20 years hence. This is especially true for nuclear power plants, which seem to be a logical solution to the South Coast Air Basin problem, and which probably should be planned 20 years in advance.

There are ominous signs that control technology alone is not able to cope with the ever-increasing growth in population and all its polluting activities. Plans have to be made *now* as to how we want the basin to look and what kind of air we want to breathe a few decades ahead. This should be a major concern of a regional planning organization, either at the state level or responsible to the state. Its plan of action must include the conservation of green areas, development of a satisfactory transportation system, and the management of our industrial complex, with an overriding regard for its effect on the environment. Such an organization may well be forced into making drastic and most revolutionary decisions; for example, the removal of polluting industries from the South Coast Air Basin to areas having better ventilation. It might have to face the gigantic task of converting the area to a totally electric economy, eliminating all fuel burning in the Basin and using only electric power, which should be generated outside the basin, for propulsion and for space heating.

LESSONS FOR THE FUTURE

In the past, control efforts have been characterized by underestimation of the

seriousness and size of the problem, misjudgment of the potential of available control techniques, and gross optimism on the degree of cooperation of industry and the community. Today we realize that we have always been too timid in setting our goals. This policy has led to a waste of effort and money for temporary solutions or remedies, when more drastic measures are required. A good example of this is in the motor vehicle industry. The industry thought that some minor adjustments of the car would suffice. Now it is clear that regardless of how much the individual vehicle emissions are reduced, the growth in the number of vehicles will eventually bring back the same old situation of air pollution. A drastic control of the motor vehicle foreshadowed by the removal of lead from gasoline and the active search for different engine types show that we have started to learn our lesson. Much the same can be said for electric power generation. An early emphasis on the development of the nuclear breeder reaction might by now have resulted in suitable alternatives to fossil-fuel power plants.

The misjudgment of the potential of our control techniques has led us to believe that an unlimited influx of industry and motor vehicles can be tolerated. We have learned that this is not so. We are now emphasizing the natural basin concept in air pollution control, and governmental structures are being proposed which can most effectively cope with this new approach.

We have also learned not to rely too much on the wholehearted cooperation of the community. The control officer is torn by pressures urging him not to rock the boat and by counterpressures which like to see him charge like a bullfighter. He has to work with a meager budget, be an engineer, a chemist, and a lawyer and finally he has to listen to tales of woe from irate citizens as well as from industry. This wonder man will soon learn that the road to survival and to accomplishment is paved with compromise and has to be travelled with patience and diplomacy. Active public participation can shift this delicate balance in favor of control. Every enforcing agency needs a strong and active public-relations and public information department. This department must educate the public, acquaint them with the control measures being taken, and explain clearly the steps necessary to obtain clean air. This means continual personal contact with citizens' groups, schools, and news media. The importance of this cannot be stressed too strongly. Much has been learned, attitudes have changed, ecology has become a household word, and almost everybody agrees that something should be done about air pollution.

With medical evidence supporting the goals set by air quality standards and with an awakened public, it is possible for enforcing agencies to act with conviction and courage and to impose stringent restrictions on emissions in order to guarantee the return to acceptable air quality in the South Coast Air Basin.

We have also learned that these agencies cannot carry the total burden. Air pollution in urban areas is an expression of poor management of our total environment, and its control goes far beyond correction of individual pollution sources.

A realistic long-range plan for air pollution control is long overdue. This plan must take into account our technical know-how but also all facets of community

living. We should have learned by now that we cannot hope to change the laws of nature, but we can change human institutions. The road is not an easy one, but the reward of breathing clean air is worth the effort.

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